(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 November 2001 (08.11.2001)

PCT

(10) International Publication Number
WO 01/84096 A1

(51) International Patent Classification[7]: G01J 3/00, G01N 21/00, 21/27, C12M 3/00

(21) International Application Number: PCT/US00/11487

(22) International Filing Date: 28 April 2000 (28.04.2000)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: SPX CORPORATION [US/US]; 700 Terrace Point Drive, P.O. Box 3301, Muskegon, MI 49443-3301 (US).

(72) Inventors: BUTTS, Charles, G.; 2 Robin Lane, Weaverville, NC 28787 (US). RUNION, Timothy, R.; 1050 Old Leicester Highway, Asheville, NC 28806 (US).

(74) Agent: LUEBBERING, Thomas, B.; Hovey, Williams, Timmons & Collins, Suite 400, 2405 Grand Boulevard, Kansas City, MO 64108 (US).

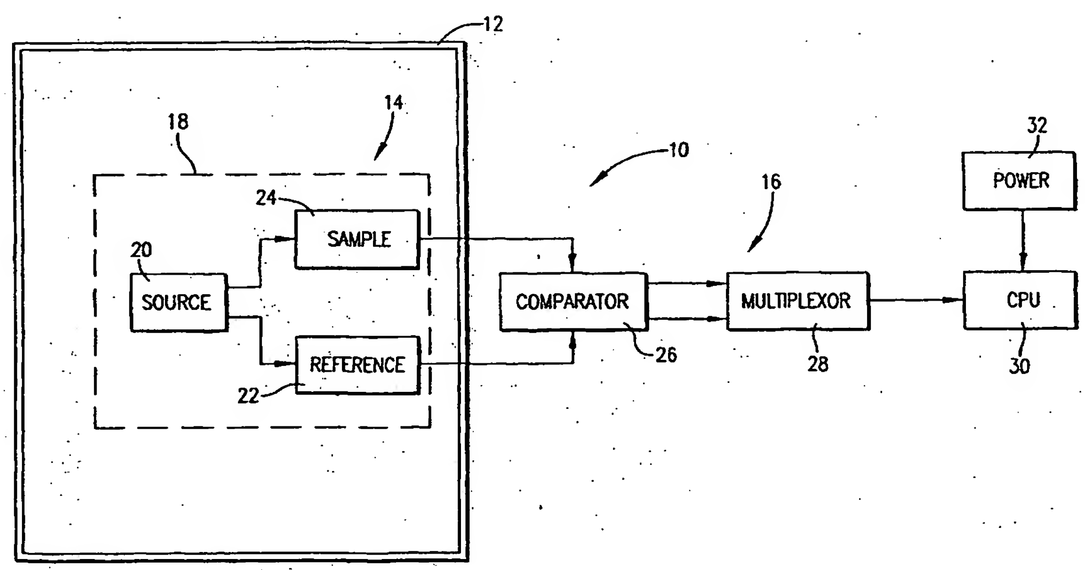
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: CO_2 GAS MEASUREMENT SYSTEM FOR A LABORATORY INCUBATOR



(57) Abstract: A gas measurement system (10) for measuring the concentration of CO_2 gas in an incubator (12) includes a radiation source (20) for radiating energy; a reference detector (22) operable to receive a portion of the radiated energy, to detect a spectral range of the energy outside of an absorption band of the gas, and to generate a signal representative thereof; a sample detector (24) to detect the spectral range of the energy within the absorption band of the gas, and to generate a signal representative thereof; and a control assembly for comparing the signals generated by the reference and sample detectors to determine the concentration of the gas in the enclosed area.

WO 01/84096 A1

CO_2 GAS MEASUREMENT SYSTEM FOR A LABORATORY INCUBATOR

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a CO_2 gas measurement system for use in a laboratory incubator. More particularly, the invention relates to a gas measurement system that more accurately measures the amount of CO_2 gas in an incubator as the components of the system degrade over time.

2. DESCRIPTION OF THE PRIOR ART

CO_2 gas is commonly introduced into laboratory incubators to facilitate cell growth and testing. Because CO_2 levels must be kept within a desired range, laboratory incubators typically include CO_2 detector assemblies for detecting the concentration of CO_2 therein. One such prior art CO_2 detector assembly includes a sensing cell containing the same environment as its incubator, an infrared (IR) source that radiates energy within the sensing cell at the absorption band of CO_2, and a detector positioned to receive the radiated energy from the source and operable to generate an output signal representative of the intensity of the received energy in the absorption band of the CO_2. The CO_2 in the sensing cell partially absorbs the energy that is within the absorption band of CO_2; therefore, the amount of energy that reaches the detector corresponds to the amount of CO_2 in the cell.

As long as the energy emitted from the source and the sensitivity of the detector remain constant, the output of the detector accurately corresponds to the concentration of CO_2 in the cell. However, over time, the amount of energy emitted from the source decreases and the sensitivity of the detector changes. Also, temperature changes can affect the operation of both the source and the detector. These changes, commonly referred to as source and detector "drift", cause inaccurate CO_2 measurements and therefore inaccurate control of CO_2 introduced into the incubator.

One prior solution to this problem is to periodically calibrate the detector assembly by evacuating the sensing cell of all CO_2 and then measuring the intensity of

the radiation received by the detector. This reading is then compared to a reading taken when the assembly was first used to determine the degradation of both the source and the detector. Although this solution is effective, it is time consuming and therefore impractical.

OBJECTS AND SUMMARY OF THE INVENTION

The present invention solves the above-described problems and provides a distinct advance in the art of incubator CO_2 measurement systems. More particularly, the present invention provides a CO_2 gas measurement system that continuously calibrates itself before each measurement to account for degradation of both its source and detector.

The gas measurement system of the present invention broadly includes a radiation source for radiating energy; a reference detector operable to receive the radiated energy, to detect a spectral range of the radiated energy outside of an absorption band of the gas, and to generate a signal representative thereof; a sample detector operable to receive the radiated energy, to detect a spectral range of the radiated energy within the absorption band of the gas, and to generate a signal representative thereof; and a control assembly for comparing the signals generated by the detectors to determine the concentration of the gas in the enclosed area. The radiation source, reference detector, and sample detector are preferably positioned in a sensing cell that contains the same CO_2 gas concentration as its corresponding incubator.

The output signal of the sample detector is sensitive to the amount of CO_2 gas in the sensing cell in a similar manner as prior art detectors. However, because the reference detector is only sensitive to energy that is outside the absorption band of CO_2, it generates a signal that is independent of the amount of CO_2 in the sensing cell. Therefore, the difference between the output signals of the two detectors corresponds to the amount of CO_2 in the sensing cell and is independent of the degradation of the source and the detectors. This allows the control assembly to continuously calibrate the system by comparing the signals generated by the two detectors.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

A preferred embodiment of the present invention is described in detail below with reference to the attached drawing figures, wherein:

Fig. 1 is a schematic diagram of a CO_2 gas measurement system constructed in accordance with a preferred embodiment of the invention and shown coupled with a laboratory incubator.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to the drawing figure, a CO_2 gas measurement system broadly referred to by the numeral 10 and constructed in accordance with a preferred embodiment of the invention is illustrated. The preferred measurement system is shown coupled with an incubator 12 and is operable for detecting and measuring the concentration of CO_2 gas therein; however, those skilled in the art will appreciate that the measurement system can be configured to measure the concentration of any gas in any enclosed area. The preferred gas measurement system 10 broadly includes a gas detector assembly referred to by the numeral 14 and a control assembly referred to by the numeral 16.

In more detail, the gas detector assembly 14 includes a sensing cell 18, a radiation source 20, a reference detector assembly 22, and a sample detector assembly 24. The sensing cell must contain the same environment as the incubator 12 and therefore may simply be an area within the incubator. Alternately, the sensing cell may be remote from the incubator and coupled therewith with piping or tubing so that the environment from the incubator can be pumped or otherwise introduced into the sensing cell.

The source 20 is positioned within the sensing cell 18 and is operable to radiate energy through the environment of the cell. The source is preferably an incandescent lamp that radiates infrared (IR) energy in the absorption band of CO_2. The source, as well as the other components of the gas detector assembly, are preferably manufactured by Digital Control Systems, Inc., of Portland, Oregon.

The present invention takes advantage of the principle that CO_2 gas is invisible to radiation at wave lengths outside of a narrow CO_2 absorption band. Therefore, radiation outside the absorption band of CO_2 passes unimpeded through CO_2. Conversely, radiation within a narrow absorption band of CO_2 is partially absorbed

by CO_2 gas. Therefore, radiation within the absorption band of CO_2 is at least partially blocked by the presence of CO_2 within the sensing cell.

The reference detector assembly 22 is positioned within the sensing cell 18 so that it at least some of the energy emitted from the source 20 impinges thereon. The reference detector assembly includes a conventional IR detector and a filter coupled therewith that passes a spectral range of the energy emitted from the source that is outside of the absorption band of the CO_2 gas present in the sensing cell. Thus, the energy in this spectral range passes unimpeded to the reference detector regardless of the amount of CO_2 gas present in the sensing cell. The reference detector's output is therefore independent of the CO_2 gas concentration in the sensing cell, but is dependent upon the brightness or intensity of the energy emitted from the source.

The sample detector assembly 24 is also positioned with the sensing cell 18 so that at least some of the energy emitted from source 20 impinges thereon. The sample detector assembly preferably includes a conventional IR detector and a filter coupled therewith that passes a spectral range of the radiated energy that is within the absorption band of CO_2. Therefore, the amount of radiated energy that reaches the sample detector is dependent upon the concentration of CO_2 gas within the sensing cell so that the output of the sample detector changes with the CO_2 gas concentration in the cell.

The control assembly 16 is coupled with the gas detector assembly 14 and is operable for analyzing the signals generated by the sample and reference detectors 22,24 to determine the concentration of CO_2 within the sensing cell 18. The control assembly includes a comparator 26, a multiplexer 28, and a microprocessor 30, all powered by a conventional power source 32.

The comparator 26 receives the output signals from both the reference detector 22 and the sample detector 24 and determines the difference therebetween. The difference between these signals corresponds to the amount of CO_2 in the sensing cell and is independent of other factors such as the degradation of the source and the detectors.

The multiplexer 28 is coupled with the comparator 26 for receiving signals therefrom, multiplexing the signals, and passing them to the microprocessor 30. The microprocessor then analyzes the signals to determine the concentration of CO_2 within the sensing cell 18 as described below. The microprocessor may be coupled with other

components such as a CO_2 valve for regulating the delivery of CO_2 to the sensing cell in accordance with the measured value of the CO_2 in the cell.

In operation, the gas detector assembly 14 is placed in our coupled with the incubator 12 or other enclosed area having a concentration of CO_2 or other gas therein. The source 20 is then turned on so that radiation emitting therefrom impinges upon the reference and sample detector assemblies 22,24. The reference and sample detectors generate output signals as described above which are in turn received by the comparator 26.

In one embodiment, the comparator first reads the output from the reference detector 22 and stores it in memory. The comparator then reads the output from the reference detector again and compares it to the stored output signal to determine if there is a difference. If there is a difference, the comparator and multiplexor 28 multiplex the difference with the output signal of the sample detector and pass the multiplexed signal to the microprocessor 30. The microprocessor then determines the CO_2 gas concentration in the sensing cell by analyzing the signals from the comparator and multiplexer.

As evident from the foregoing description, the CO_2 gas measurement system 10 of the present invention continuously calibrates itself prior to each CO_2 measurement to compensate for degradation of the source 20 and the reference and sample detectors 22,24. This enables the system to accurately and quickly determine the CO_2 gas concentration in the sensing cell 18 without first evacuating the cell of all CO_2 gas.

Although the invention has been described with reference to the preferred embodiment illustrated in the attached drawing figures, it is noted that equivalents may be employed and substitutions made herein without departing from the scope of the invention as recited in the claims. For example, although the invention is particularly useful for measuring the concentration of CO_2 gas in an incubator, it may also be used to measure the concentration of other gases in other enclosed areas.

Having thus described the preferred embodiment of the invention, what is claimed as new and desired to be protected by Letters Patent includes the following:

CLAIMS:

1. A gas measurement system for measuring the concentration of a gas in an enclosed area comprising:

a radiation source for radiating energy;

a reference detector operable to receive a portion of the radiated energy, to detect a spectral range of the energy outside of an absorption band of the gas, and to generate a signal representative thereof;

a sample detector operable to receive a portion of the radiated energy, to detect a spectral range of the energy within the absorption band of the gas, and to generate a signal representative thereof; and

a control assembly for comparing the signals generated by the detectors to determine the concentration of the gas in the enclosed area.

2. The gas measurement system as set forth in claim 1, wherein the gas is CO_2.

3. The gas measurement system as set forth in claim 1, the enclosed area including a laboratory incubator.

4. The gas measurement system as set forth in claim 1, wherein the radiation source is an infrared lamp.

5. The gas measurement system as set forth in claim 1, the control assembly including-

a comparator for comparing the signals generated by the reference and sample detectors,

a multiplexer coupled with the comparator for multiplexing the signals, and

a controller coupled with the multiplexer for receiving the multiplexed signals and for determining the concentration of the gas in the enclosed area as a function thereof.

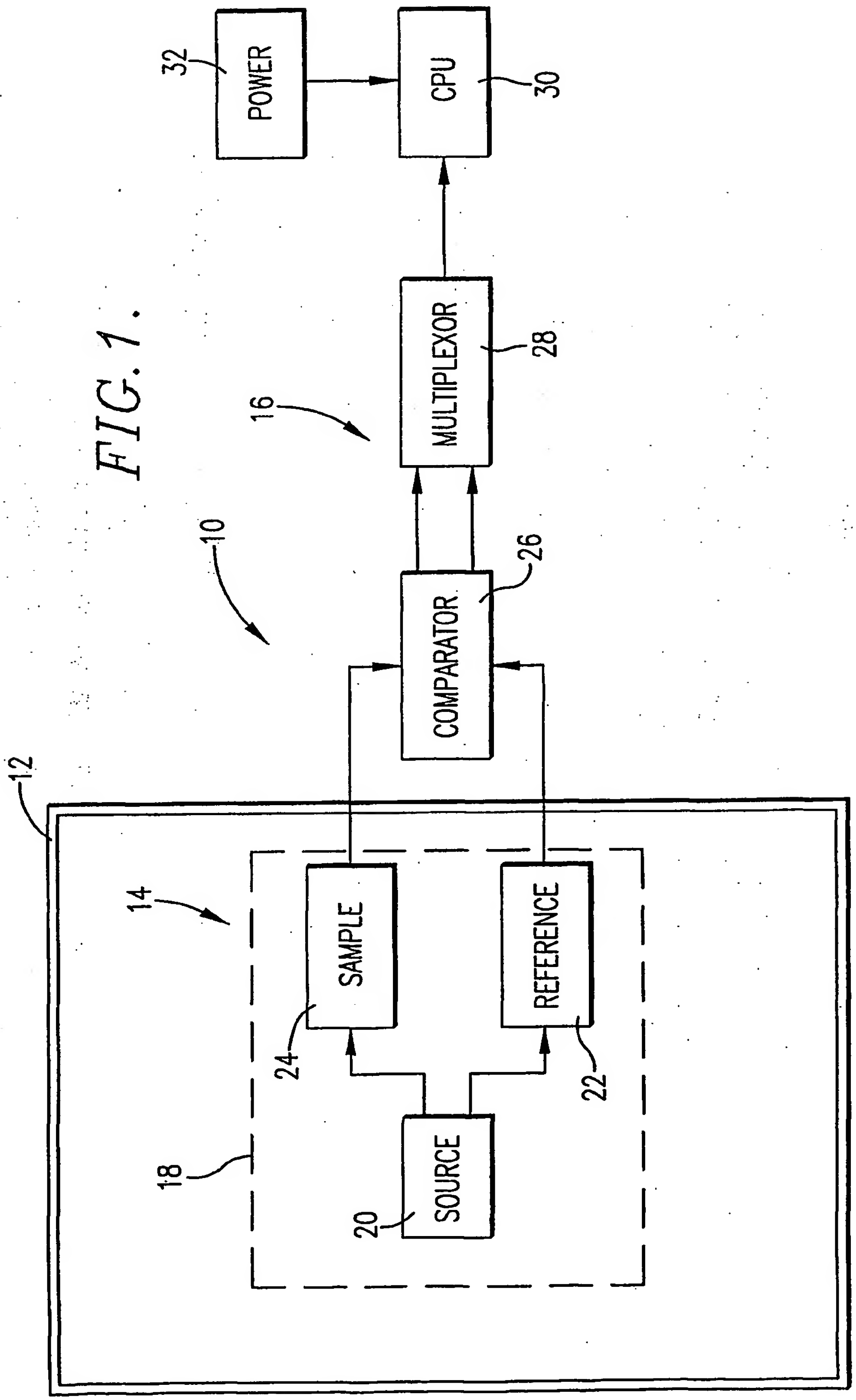

POWER
CPU
MULTIPLEXOR
COMPARATOR
SAMPLE
REFERENCE
SOURCE
10
12
14
16
18
20
22
24
26
28
30
32

FIG. 1.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/11487

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G01J 3/00; G01N 21/00, 21/27; C12M 3/00
US CL :356/51, 433, 434, 435, 437; 422/82.09; 435/303.1, 303.2
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 356/51, 433, 434, 435, 437; 422/82.09; 435/303.1, 303.2

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 3,860,818 A (STADLER et al.) 14 January 1975, col. 2, lines 36-55; col. 3, lines 3-24.	1,2,4,5 — 3
X — Y	US 4,692,621 A (PASSARO et al.) 08 September 1987, col. 4, lines 22-42; col. 6, lines 41-47.	1,2,4,5 — 3
X — Y	US 5,444,249 A (WONG) 22 August 1995, col. 3, lines 34-41; col. 7, lines 27-39; col. 9, lines 24-42; figure 9.	1,2,4,5 — 3
Y	JP 405000077 A (MIYOSHI) 08 January 1993, see abstract.	3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 AUGUST 2000	28 AUG 2000

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	DAVID REDDING
Facsimile No. (703) 305-3230	Telephone No. (703) 308-0651